

Animal breeding systems: Aquaculture

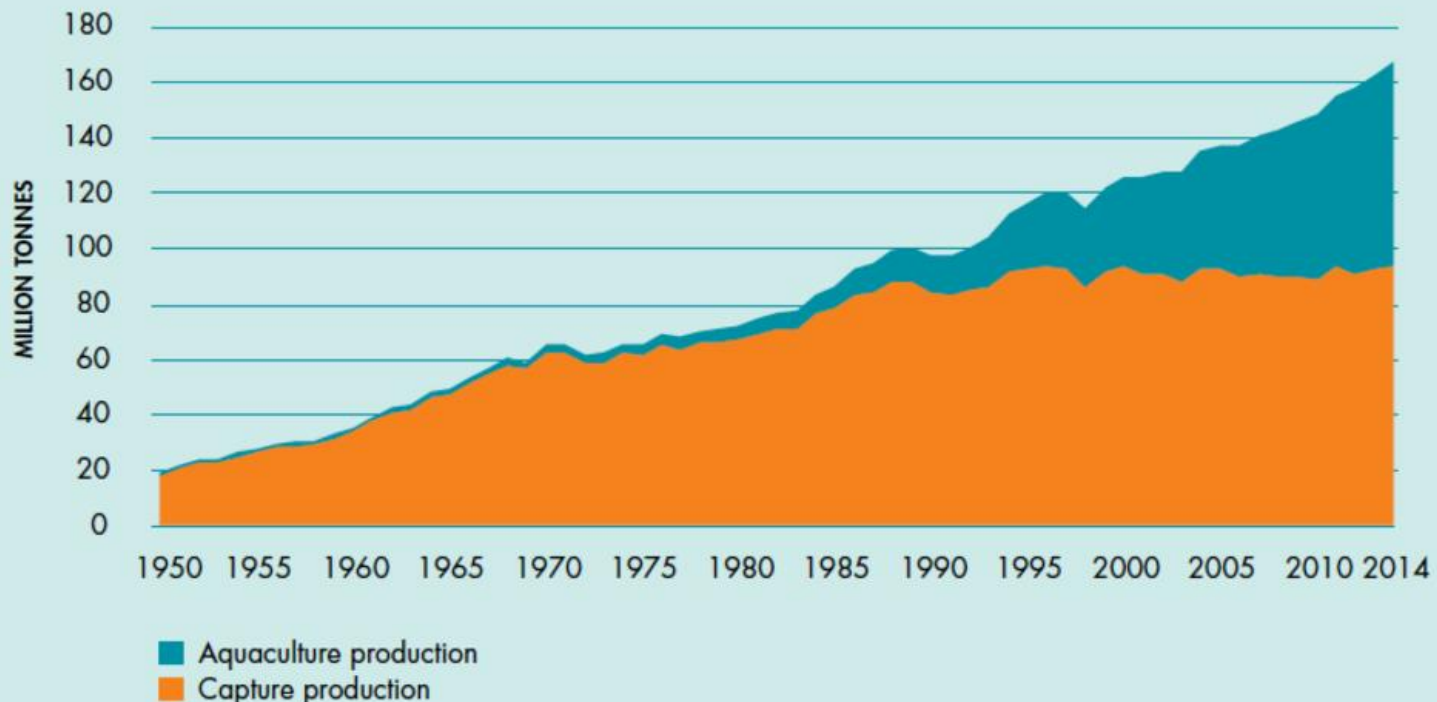


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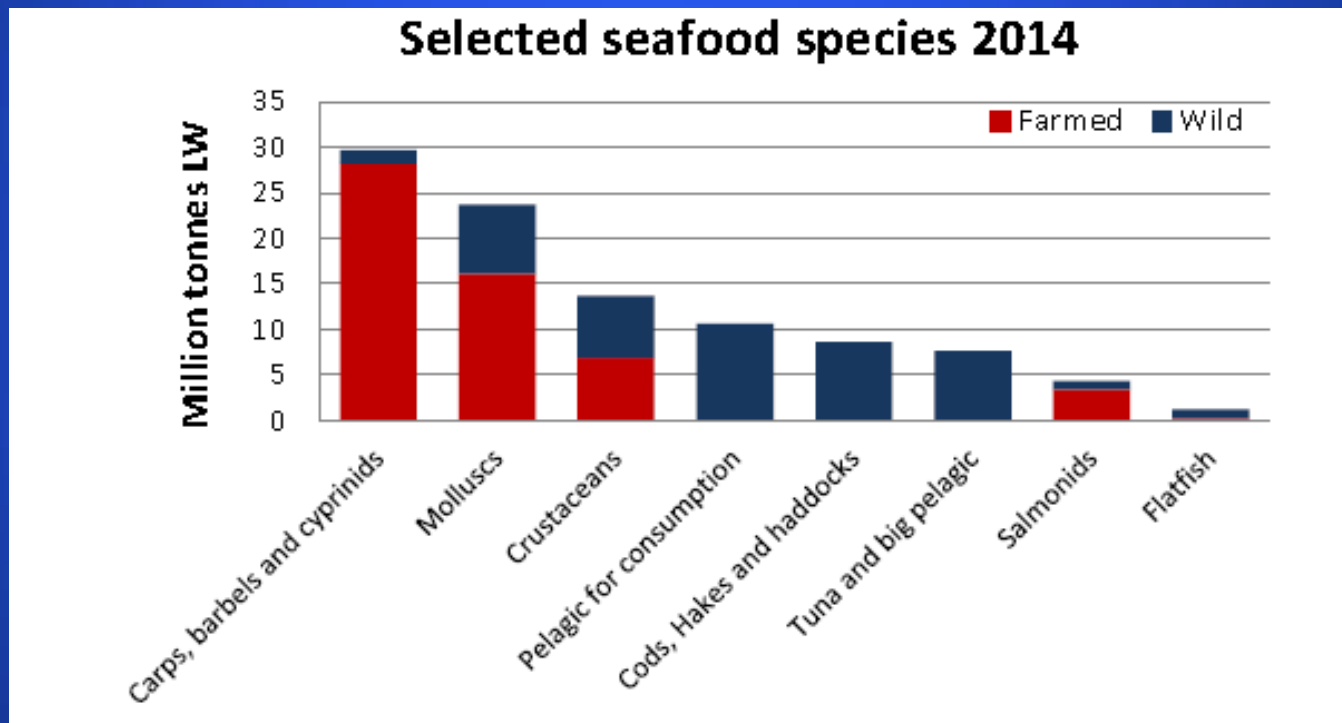
Fisheries is the last major food system where harvest from the wild remains important, ...and **aquaculture provides a large and growing part of our supply of fisheries products**

FIGURE 1

WORLD CAPTURE FISHERIES AND AQUACULTURE PRODUCTION



The contribution of aquaculture varies among species groups



(Marine Harvest 2016)

Aquaculture is a rapidly evolving sector

- Growing rapidly – 5.8% in 2014 (FAO)
- Some sectors are “mature”, others are still emerging
- New species are coming into culture; culture systems are still being developed; some cultured species are still being domesticated
- Genetically improved lines are at very different stages of development among sectors and regions
- **Distribution of genetically improved lines reflects the structure of each sector** (reflects sector “maturity”, vertically integrated corporation vs. family-scale farms)

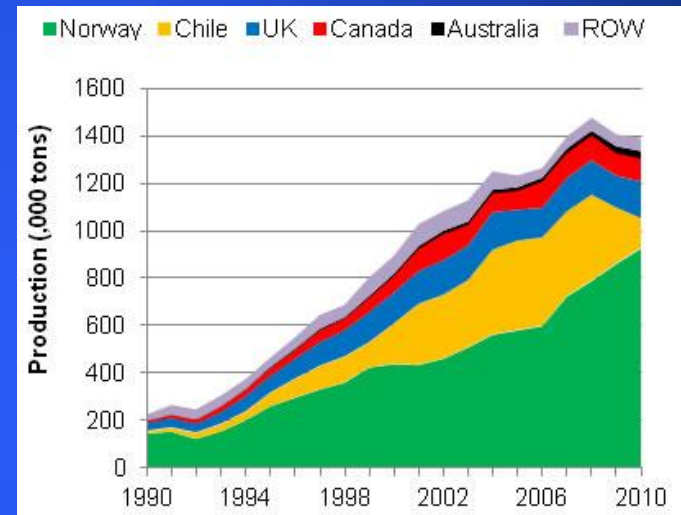
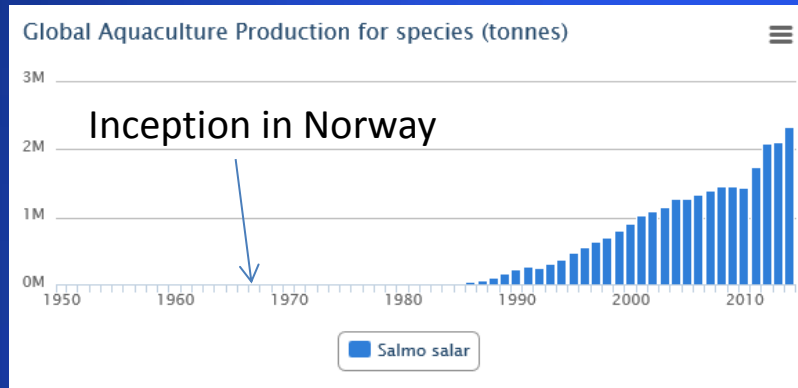
Case studies of key sectors of aquaculture

- World production
- Culture systems
- Industry structure
- Development and distribution of genetically improved lines
- Prospects for GE lines



Atlantic salmon

- *Salmo salar*

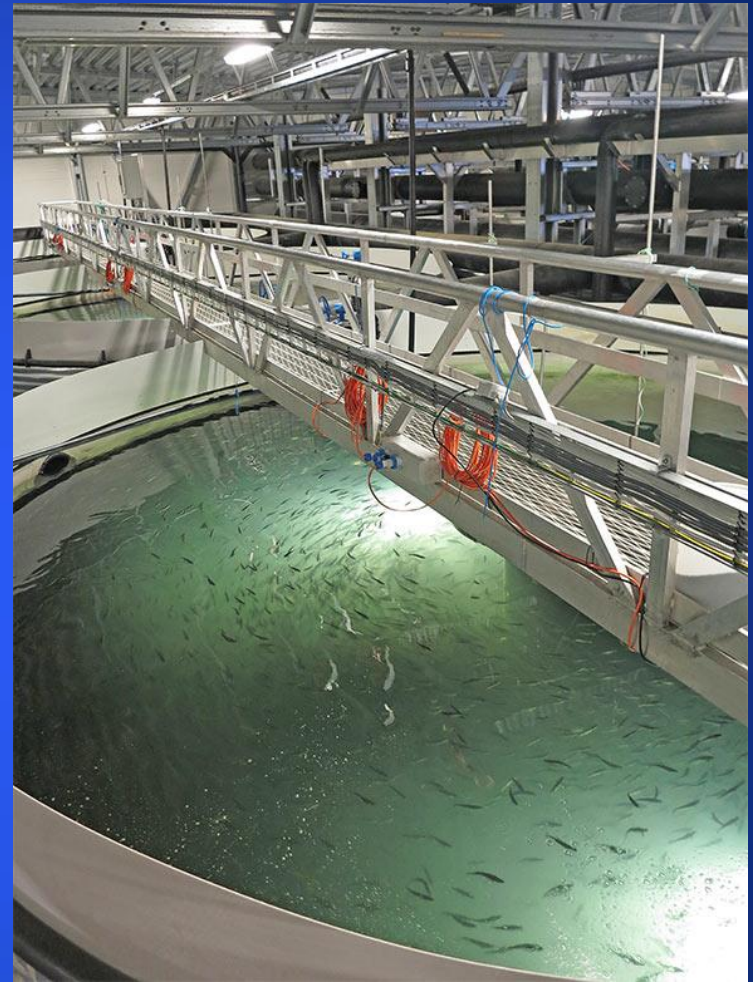


- Classical production system:



Atlantic salmon

- Pre-smolts long cultured on-shore
- Can *grow-out* be shifted onshore?
- Large RAS are being developed in order to deal with issues regarding sea lice outbreaks (Norway), algae blooms (Chile), and escapes, ...
- It is a challenge to break even producing salmon in RAS
- ...which may create an opening for producing GM fish under strict confinement



Kruger Kaldnes RAS, Veolia Water Technologies

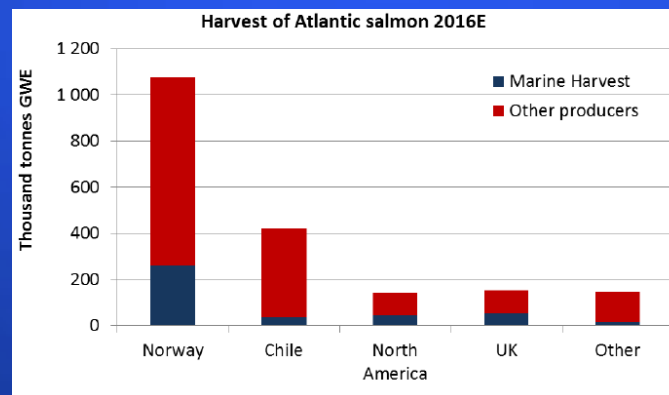
Industry structure:

- Dominated by a few producers within each country:

	Top 10 Norway	Harvest	Top 5 UK ¹⁾	Harvest	Top 5 North America ¹⁾	Harvest	Top 10 Chile	Harvest
1	Marine Harvest	254 800	Marine Harvest	50 100	Cooke Aquaculture	42 000	Empresas Aquachile	63 000
2	Salmar	136 400	Scottish Sea Farms	27 000	Marine Harvest	40 100	Marine Harvest	62 500
3	Lerøy Seafood	135 000	The Scottish Salmon Co.	25 600	Mitsubishi (Cermaq)	21 000	Mitsubishi	60 000
4	Mitsubishi (Cermaq)	58 000	Cooke Aquaculture	19 000	Grieg Seafood	14 300	Salmones Multiexport	51 000
5	Nordlaks	39 000	Grieg Seafood	16 400	Northern Harvest	13 000	Camanchaca	39 000
6	Nova Sea	37 400					Australis Seafood	38 100
7	Midt-Norsk / Bjørøya	32 000					Pesquera Los Fiordos	30 000
8	Grieg Seafood	31 700					Blumar	25 800
9	Norway Royal Salmon	27 900					Cooke Aquaculture	25 000
10	Alsaker Fjordbruk	27 000					Ventisqueros	22 000
	Top 10	779 200	Top 5	138 100	Top 5	130 400	Top 10	416 400
	Total	1 110 800	Total	149 700	Total	139 900	Total	531 800
	Total	70 %	Total	92 %	Total	93 %	Total	78 %

Note: All figures in tonnes GWE for 2015
¹⁾ UK and North American industry are best described by top 5 producers.

- Some producers are multinational companies (Marine Harvest, Cooke Aquaculture, Mitsubishi, ...)

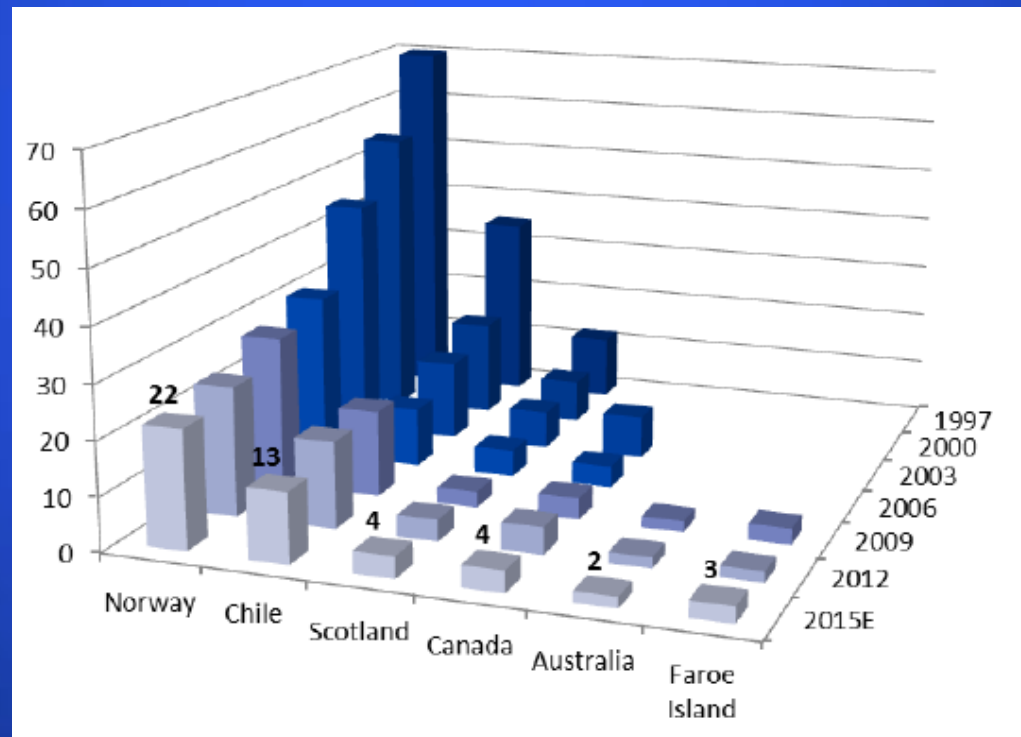


e.g., Marine Harvest has operations on three continents

Atlantic salmon

Industry structure:

- Consolidation is ongoing

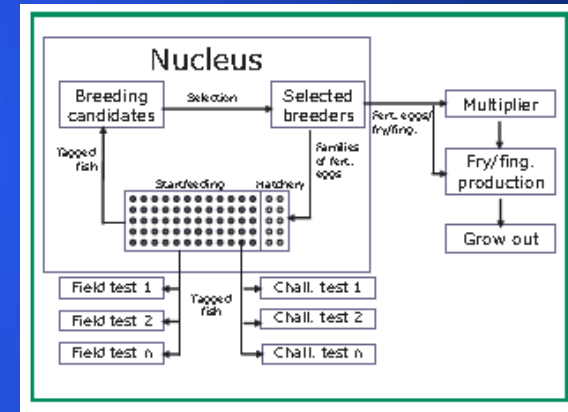


Atlantic salmon

- Development and distribution of genetically improved lines:
- Since ~1970, Norwegian national program
- Classical selective breeding for growth rate, FCE, carcass quality, disease resistance
- Today, ten competing companies and organizations selectively breed Atlantic salmon
- → more secrecy, little reporting in scientific literature...

Atlantic salmon

- Sophisticated nucleus breeding design:
- Full-sib and paternal half-sib family group production onshore
- Sea unit → rearing breeding candidates
- A few sea-unit locations for performance testing
- 4-year generation time → multiple year-classes in evaluation at a time
- High-capital operation!
- “Multipliers” produce seed-stock for sale to growers



(Gjerde et al., nd)

Atlantic salmon

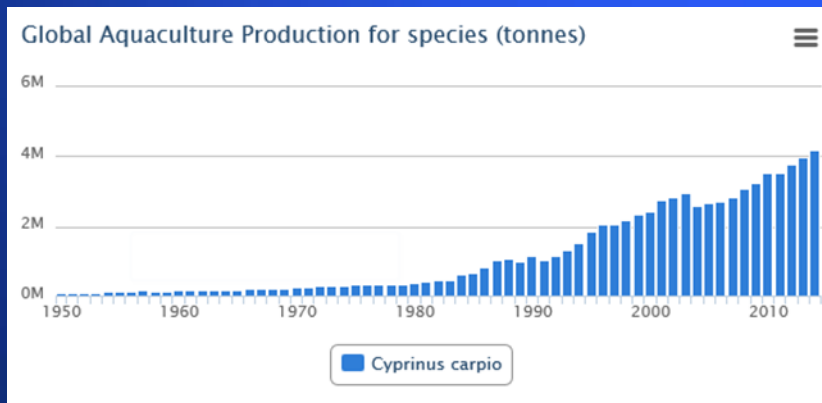
- Virtually *all* Atlantic salmon in production is genetically improved
- An *exceptional* situation within aquaculture



Carps



- Most-raised species complex world-wide
- Have been raised in China for 2,000 to 4,000 years



Carps

- Two major Asian *polyculture* systems:
- Chinese major carps:
 - Silver carp - phytoplanktivore
 - Bighead carp - zooplanktivore
 - Common carp – benthic invertivore
 - Grass carp - herbivore
- Indian major carps:
 - Catla – surface foods
 - Rohu - herbivore
 - Mrigal – detritivore
- Common carp raised in *monoculture* in Europe
- Programmatic genetic improvement for common carp only
- *Let's focus on common carp*



Common carp

- Has a large geographical range → genetically differentiated populations (~land races)
- Aquaculture ponds traditionally were stocked with fry collected from rivers.
- Some limited ability to get carp to spawn in ponds using mats
- Semi-domesticated carp races developed within this system
- Some selection practiced, → local/regional varieties, e.g., Chinese bigbelly, Indonesian Madalayan, Japanese koi, Russian Ropsha, European Galician, Hungarian Dinnes, Israeli Dor-70, ...



Common carp

- Artificial propagation techniques (induced spawning) 1960s → more purposeful, science-based selection for scalation, coloration, growth rate, conformation, disease resistance, fertility
- Selection and crossbreeding were applied in USSR, Hungary, ...
- Asian carps not systematically bred (exc. koi)
- Beginning of a GIFT-like genetic improvement program for carps in past few years



Common carp

Industry structure (generality):

- Government breeding stations → improved broodstock
- Private-sector producer → seedstock
- Farmers → grow-out

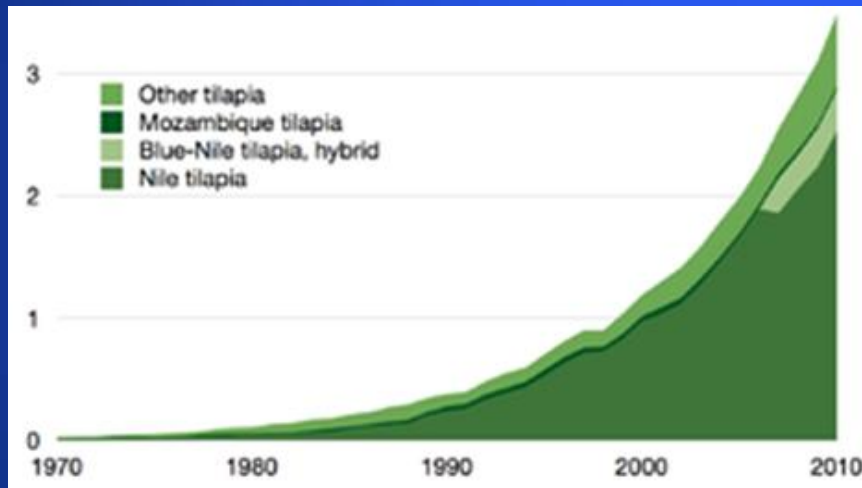


Tilapias

- Unique reproductive system; mouth-brooders. Parental care → “anyone” can rear them
- Amenable to production in a variety of systems, from low-input pond aquaculture to super-intensive recirculating aquaculture systems



Tilapias



Nile tilapia – *Oreochromis niloticus*



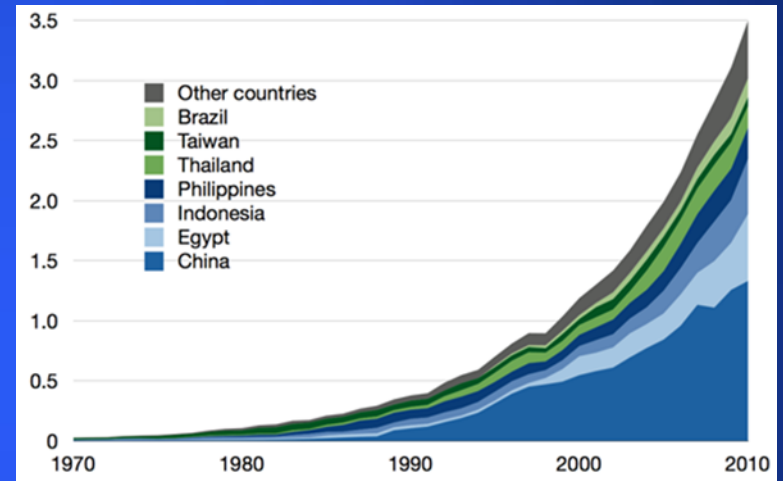
Blue tilapia – *O. aureus*



Mozambique tilapia – *O. mossambicus*

Tilapias

- Tilapia will feed a billion people and contribute to:
- Food security in Africa and Asia, and
- Commercial enterprises world-wide



Tilapias

Industry structure:

- Mostly small producers who buy seed-stock from local/regional seed-stock producers.
- May or may not be genetically improved stock
- May or may not be monosex stocks



- In developed countries, emergence of larger producers with some degree of vertical integration; some have in-house selective breeding programs

Tilapias

- Development and distribution of genetically improved lines:
- Because of mouth-breeding habit, easy to spawn and selective breeding is relatively straightforward



E.G.: Selective breeding of fast-growing, white hybrid *O. niloticus* at Blue Ridge Aquaculture, Martinsville, VA, USA

Tilapias

- Many genetically improved lines...
- Breeders and producers label their strains with the names of institutions (University of Stirling), companies (Blue Ridge Aquaculture), or even individuals (Mike Sipe).
- Lines may be proprietary; may be sold regionally or even internationally, but most have but limited impact.
- A notable breeding program, international impact: the Genetically Improved Farmed Tilapia (GIFT) Project:
- A collaboration between the Philippine Bureau of Fisheries and Aquatic Resources, two Philippine universities, AKVAFORSK of Norway, and ICLARM (now the World Fish Center).
- Germplasm collected from Egypt, Ghana, Senegal, and Kenya, and four Philippine farm stocks → genetically mixed base population → combined family and within-family selection strategy implemented through nine generations (Ponzoni et al., 2011).

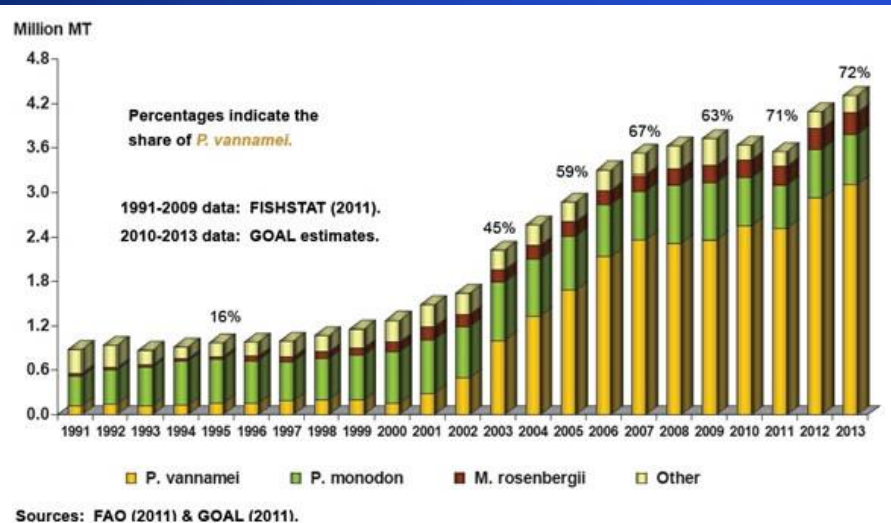
Tilapias

- Genetic gain for growth rate over nine generations was 64% relative to the founding population (Khaw et al., 2008).
- Results of the GIFT project generated interest from developing countries in Asia, the Pacific, and Africa.
- The GIFT strain has been disseminated to 11 countries in Asia (Gupta and Acosta, 2004).



- The WorldFish Center decided *not* to introduce the GIFT strain into countries where *O. niloticus* is indigenous, but rather to help countries apply the GIFT methodology to genetic improvement of indigenous tilapias, e.g., Akosombo strain in Ghana.

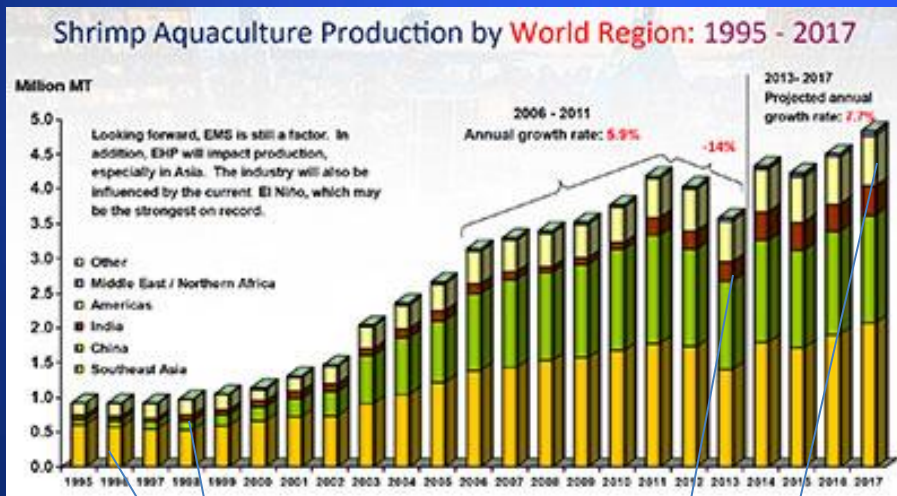
Shrimps



Pacific white shrimp - *Penaeus vannamei*



Giant tiger prawn – *Penaeus monodon*



Thailand, Vietnam, Indonesia

China

India

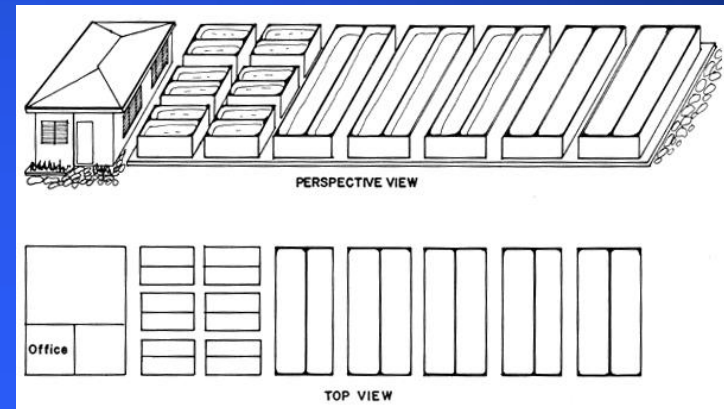
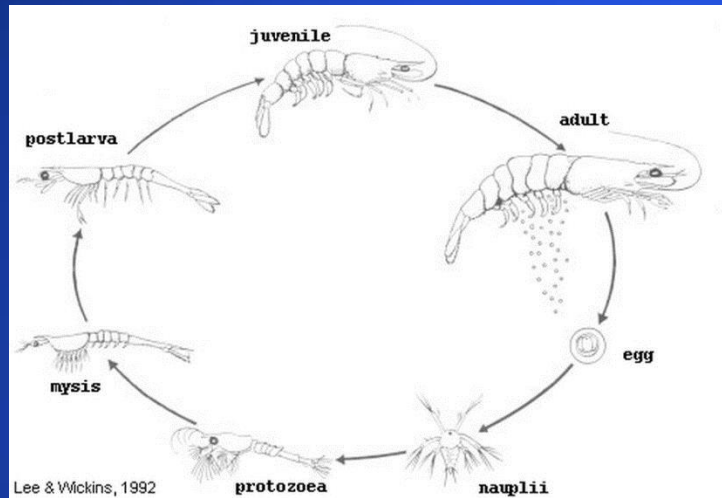
Brazil, Ecuador, Mexico



Figure 1. Giant freshwater prawn (*Macrobrachium rosenbergii*)

Giant freshwater prawn – *Macrobrachium rosenbergii*

Shrimp production



Shrimps

- Major breeding issues:
- Growth rate
- Resistance to disease, esp. viral diseases (Taura syndrome, white-spot syndrome, early mortality syndrome, infectious hypodermal and hematopoietic necrosis, ...)
- SPF (specified-pathogen free) stocks



Taura syndrome



White-spot syndrome

Shrimps

- Industry structure and development and distribution of genetically improved lines: A continuum:
- From local seed-stock or grow-out producers (little to no genetic improvement or biosecurity)
- To regional shrimp breeding programs (next slide)
- To vertically integrated multinational companies, e.g.:
- CPB-Group, which owns SIS (Shrimp Improvement Systems), which markets selectively bred, SPF Pacific white shrimp PLs and broodstock
- Breeding facilities in Florida, Hawaii, Singapore, India (and partner in Indonesia)
- Lines selected for growth, fecundity, and disease resistance for 20 generations



Shrimps

- Other shrimp genetic improvement programs:
- Other U.S.-based SPF programs (all in Hawaii – hub to Asia, where demand is): Molokai Broodstock Company, Waimea Aquatic Laboratory, Moana Technologies, Molokai Sea Farms International, Oceanic Institute, SIS)
- CPP (Thailand)
- CENIACUA (Columbia) – Centro de Investigacion de la Acuicultura de Colombia – 10 generations of selection for survival and growth
- Concepto Azul (Ecuador) – uses molecular techniques to find disease survivors which do not show pathogens, and breeds them to find resistant animals
- Genearch Acuicultura, Ltda. (Brazil) – selective breeding
- Others...

Some key points

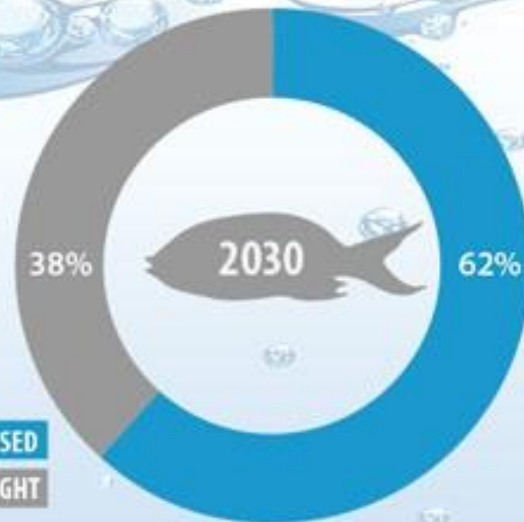
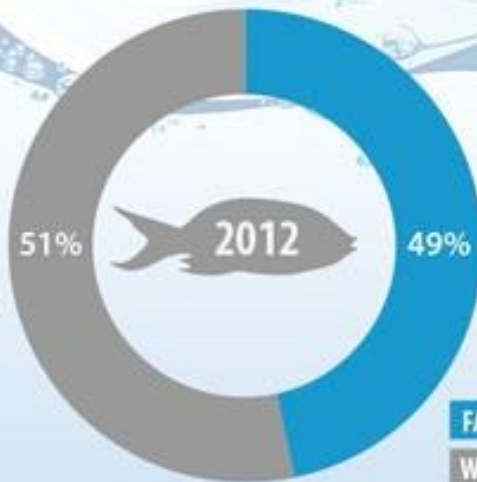
- Aquaculture is growing dramatically in important to human food security
- Aquaculture is not one sector, it's a series of independent sectors on very different trajectories
- Use of genetically improved lines:
 - Varies between sectors
 - Depends heavily on culture systems and industry structure
 - Will need to increase to meet need

GLOBAL SEAFOOD CONSUMPTION

NOW

vs

FUTURE



FARM RAISED

WILD CAUGHT